EFFECTS OF WEEDY FIELD MARGINS ON *MYZUS PERSICAE* (HEMIPTERA: APHIDIDAE) IN A BROCCOLI AGROECOSYSTEM

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Abstract.—Increases in vegetational diversity have been associated with reductions in numbers of herbivorous insect pests in many agricultural settings. One manifestation of increased vegetational diversity is the inclusion of weedy vegetation around crop plots. Plots of broccoli in a agroecosystem field study were surrounded by either (i) bare ground, or (ii) weedy margins, and numbers of both apterous and alate green peach aphids, *Myzus persicae* (Sulzer), on broccoli were recorded. Cages designed to exclude aphid predators and parasitoids were placed on broccoli plants in both types of treatment plots. Broccoli plots surrounded by bare ground had aphid densities four times as high as broccoli plots surrounded by weeds. Furthermore, alate aphid densities in plots surrounded by bare ground were five times those in weedy plots. This result coupled with the results of the exclusion cage experiment indicate that alate colonization may play an important role in the efficacy of weedy margins as a means of reducing aphid pests on broccoli.

Key Words.—Insecta, vegetational diversity, *Myzus persicae*, broccoli, integrated pest management.

For the past few decades, much effort has been put into developing protocols for deploying vegetational diversity in agroecosystems in order to reduce insect pest populations (Sheenan 1986, Russell 1989, Andow 1991, Tonhasca & Byrne 1994). Past theory and experiments suggest that increased diversity in crop fields can reduce herbivorous pests by interfering with colonization of crop plants, enhancing natural enemy populations, or both (Root 1973, Cromartie 1975, Costello 1995). I performed a field experiment in order to determine whether weedy margins around plots of broccoli (*Brassica oleracea* (L.)) were effective in reducing densities of the herbivorous green peach aphid (*Myzus persicae* (Sulzer)). Furthermore, mechanisms underlying differences in aphid densities across treatments were explored by manipulating insect populations within plots with predator-exclusion cages, as well as documenting the abundance and position of alate aphid colonists within plots.

METHODS AND MATERIALS

The field experiment was conducted during the summer of 1998 at an experimental farm approximately 70 km south of Seattle at the Washington State University Research and Extension Center in Puyallup, Washington, U.S.A. The design consisted of square plots of broccoli (*Brassica oleracea*) 2.5 m × 2.5 m in dimension, surrounded by a 1 m margin of either (1) bare ground, or (2) weeds. Broccoli plants within plots (16 per plot) were all spaced 0.5 m apart from each other; weeds were allowed to colonize and grow naturally.

Broccoli plants were grown from seed (Emperor Fl variety, Osborne Seed Co.,

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Mt. Vernon, Washington) in a greenhouse in late May. Seedlings were transplanted from the greenhouse into the field during the last week of June. Plants were then irrigated with an overhead sprinkler system, and areas around them were regularly cultivated by hand for several weeks. Thirty-six plots were established in the field: eighteen with weedy margins, eighteen with bare ground margins. Weeds in plot margins consisted primarily of *Amaranthus powellii* S. Watson, *Chenopodium album* (L.), *Echinochloa coluna* (L.), *Echinochloa crus-galli* (L.), and *Cirsium arvense* (L.). Plots were laid out in three blocks (each containing six of each type of plot), with 5.5 m of bare ground separating plots in order to discourage insect movement between plots.

On 14 Aug predator exclusion cages (0.5 m × 0.5 m × 0.75 m = 0.1875 cubic meters) constructed of wood and reemay (a horticultural cover cloth) were placed over one plant in each plot. These cages were designed to minimize the access of natural enemies such as ladybird beetles (e.g. *Coccinella septempunctata* (L.), *C. transversogutta* (Brown), *Adalia bipunctata* (L.)) and parasitoids (e.g. *Diaretiella rapae* (L.)). An additional cage, with two sides open, was placed in each plot in order to act as a "sham" cage and to assess any effects that the cage itself might have on aphid densities.

Over a period of three days beginning on 19 Aug, *M. persicae* were visually counted on a subsample of eight plants in each plot (particular plants were determined by a random number generator) in all three blocks. In addition, aphids on both caged and "sham" caged plants were visually counted. In all cases, the entire surface of each sampled plant was examined thoroughly, and the number of alate and apterous aphids as well as the location of the plant within the plot (e.g., interior or edge) were noted. Height and diameter of a subsample of plants (eight per plot) were recorded and used to calculate a cylindrical volume estimate of plant size for each plot.

An analysis of variance (ANOVA) (Wilkinson 1992) was performed on the mean number of aphids per plant per plot with block and margin type as factors (n = 6 plots × 3 blocks = 18 for each margin treatment) to assess the influence of plot margin type on aphid densities for both alate aphids and total number of aphids. ANOVA was also used to compare the mean number of aphids per caged plant vs. the mean number of aphids per sham cage plant (n = 12 plots × 3 blocks = 36 for each margin treatment) in order to quantify the effect of excluding predators. Finally, ANOVA was further used to compare the mean number of aphids per plant found on interior vs. exterior plants within a plot (n = 12 plots × 3 blocks = 36 for each plant position). Where necessary, data used in ANOVA were transformed using log (x + 1) in order to meet assumptions of normality.

A simple measure of plant size (cylindrical volume, calculated from height and diameter measurements) was calculated from a subsample of eight plants in each plot, and comparisons were made between mean plant size in plots with bare ground and weedy margins.

RESULTS

Myzus persicae densities were strongly influenced by the type of margin surrounding broccoli plants (Table 1), with the mean number of aphids more than four times higher in plots with bare ground margins than in plots with weedy margins (Fig. 1). Likewise, alate densities were strongly affected by margin type

Table 1. Analysis of variance for *M. persicae* in weedy and bare ground margin plots.

Source of variation	df	SS	F	P
Total Aphids				
Block	2	0.1	0.91	0.415
Margin type	1	2.9	42.04	<0.001
Error	32	2.2		
Alate Aphids				
Block	2	1.187	10.255	<0.001
Margin type	1	7.753	134.008	<0.001
Error	356	20.596		

(Table 1), with nearly five times as many alate aphids in plots surrounded by bare ground than in plots surrounded by weeds (Fig. 2). At the same time, there was no difference in the proportion of alate aphids found in each treatment type (1.21% in bare ground plots, 1.20% in weedy plots; z = 0.148, $P > 0.05$).

The presence of predator-exclusion cages exerted a strong influence on aphid densities (Fig. 3), with significant differences between caged and sham plants for both weedy and bare ground margin plots (Table 2). Furthermore, there was a significant interaction between predator exclusion and margin type (Table 2). Aphid densities on plants in sham cages were not significantly different than those on plants without any type of cage ($P > 0.05$, unpaired *t*-test), indicating that there was no measurable effect of cages *per se* on aphid densities.

Finally, aphid densities were no higher on plants situated on the outside edge of plots than on plants in the interior ($n = 72$, F = 1.59, df = 1, $P = 0.211$). The presence or absence of weeds in plot margins did not influence the within-plot distribution of aphids, as evidenced by the lack of any significant interaction between margin type and plant position ($n = 72$, F = 0.65, df = 1, $P = 0.423$). Furthermore, the proportion of alates on edge plants was no different than the proportion found on interior plants for both weedy margin plots (z = 0.58, $P >$
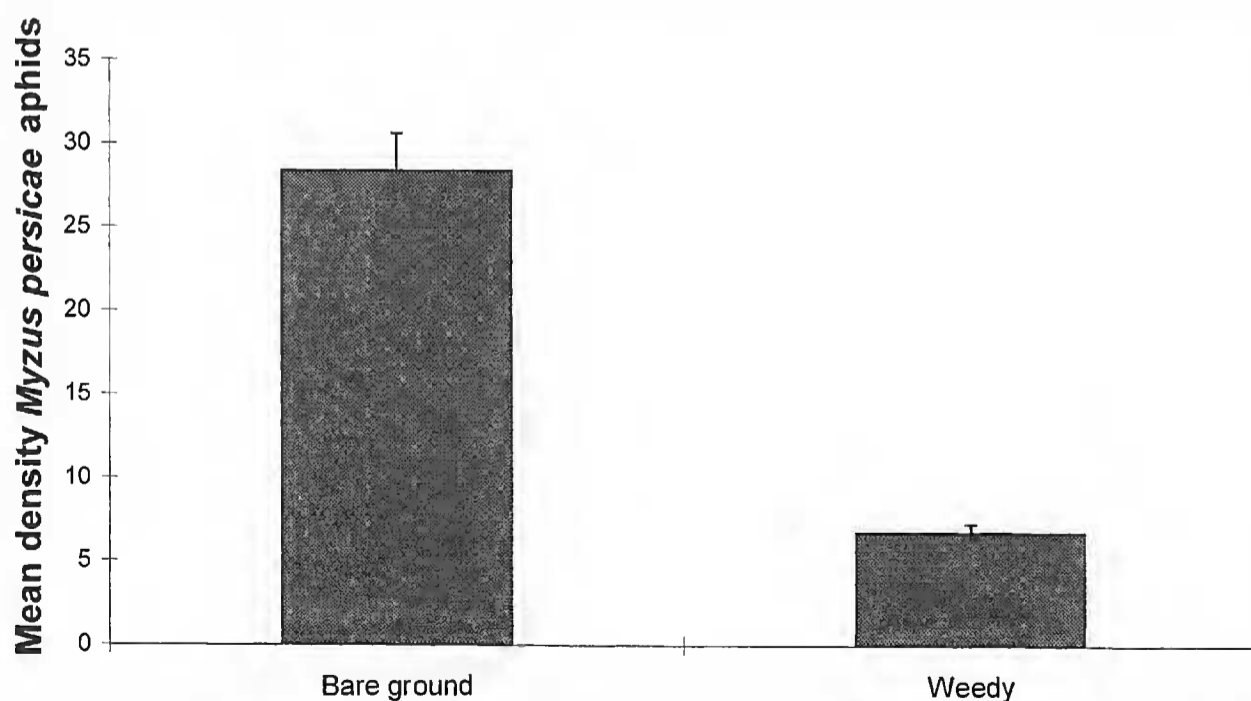

Figure 1. The influence of weedy margins on the density of *M. persicae*. Means are grouped by plot; bars represent SE for $n = 18$.
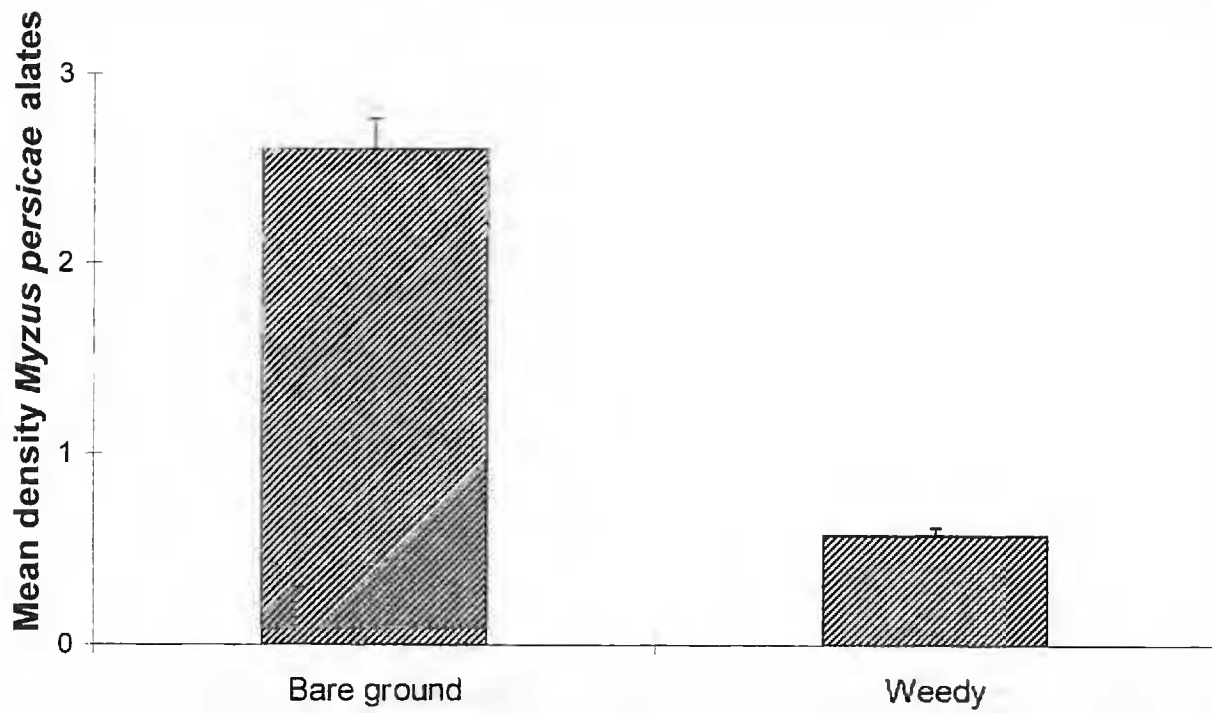
Figure 2. The influence of weedy margins on the density of *M. persicae* alates. Means are grouped by plot; bars represent SE for $n = 18$.

0.05) and bare ground margin plots ($z = 0.62$, $P > 0.05$). A comparison of plant size (cylindrical volume) among plots revealed that plant size in plots with bare ground margins was the same size as plant size in plots surrounded by weeds ($P > 0.05$, unpaired *t*-test).

DISCUSSION

For decades, the focus of much research has been on developing sound ecological techniques for reducing our reliance upon chemical pesticides for control
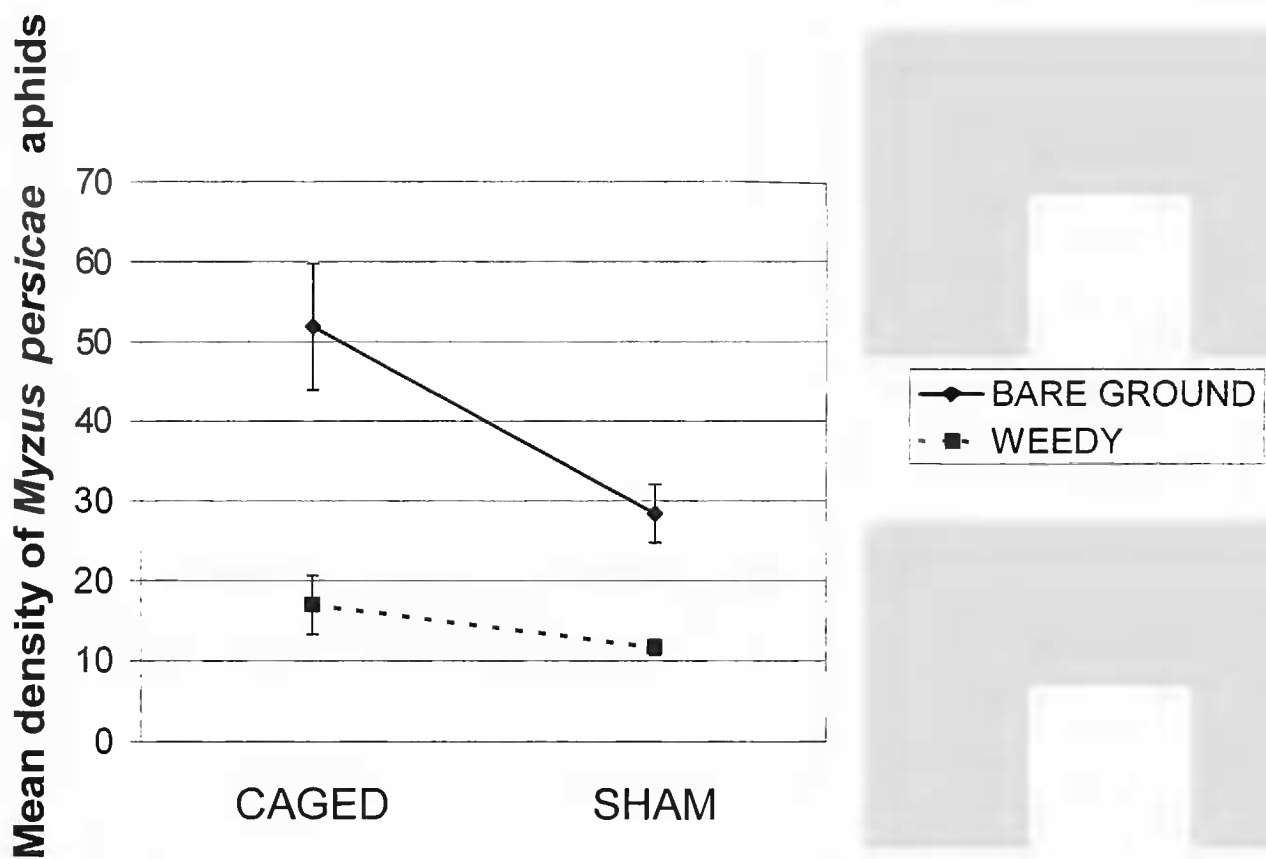

Figure 3. Effect of predator exclusion cages on density of *M. persicae*. Means were taken for each of three replicates (bars represent SE for $n = 3$).

Table 2. Analysis of variance for *M. persicae* in caged and uncaged (sham cage) plots.

Source of variation	df	SS	F	*P*
Block	2	8736.08	12.17	< 0.001
Margin type	1	11960.89	33.33	< 0.001
Cage type	1	3726.72	10.38	0.002
Margin × Cage	1	1494.22	4.16	0.046
Error	62	22249.19		

of insect herbivore pests (Banks & Stark 1998). Although the evidence is far from unequivocal (Andow 1991), many studies have suggested that the judicious use of landscape and cultural manipulations may reduce pest populations below economic thresholds, at least at certain times during the growing season (Risch et al. 1983). In particular, several studies have indicated that incorporating weedy vegetation into or around crop fields may effectively diminish pest populations (Cromartie 1975, Horn 1981, Shelton & Edwards 1983). The current experiment supports these results, although a thorough understanding of the mechanisms responsible for reduced herbivore densities in weedy margin plots remains an obstacle to applying these results to real farming scenarios.

The fact that densities of alate *M. persicae* were substantially higher in plots surrounded by bare ground suggests that the four-fold difference in densities in total aphids between bare ground and weedy margin plots (Fig. 1) may be explained by higher colonization into plots surrounded by bare ground. As plants were sampled for herbivores near the peak of alate colonization for the growing season, and aphid densities were well below the level that would stimulate new alate production (Banks, personal observation), the alates recorded most likely were recent arrivals into the broccoli field. The higher densities of alates in plots surrounded by bare ground suggests that preferential colonization of aphids into plots with bare ground margins may have been influential in generating differences in aphid densities between treatments. This is in keeping with previous work that indicates that the stark visual contrast between bare ground and crop vegetation (in this case, broccoli) is a critical cue enabling herbivores such as *M. persicae* to colonize host plants (Costello 1995).

The significant interaction between margin type and predator exclusion cages (Table 2) indicates that it may be worthwhile to explore further the impact of natural enemies on herbivore populations. While the data collected for this study were limited to alate and apterous aphid densities, a more detailed examination of the effects of weedy margins and exclusion cages on specific predators/parasitoids in the broccoli system is warranted. In particular, as coccinellid numbers were low during the growing season (Banks, personal observation), it is likely that the exclusion cages had more of an impact on aphid parasitoids (e.g., *D. rapae*). In addition, although microclimates influenced by sham cages were probably similar to those generated by full cages, it is possible that temperature differences inside the exclusion cages affected aphid growth and survival. Additional data (e.g., microclimate, observational-behavioral) in conjunction with the data reported here would be useful in interpreting better the margin-cage interaction.

Although this study suggests it may be worthwhile to incorporate weedy margins into an integrated pest management (IPM) program for cruciferous vegeta-

bles, several aspects of the experimental design warrant further examination. For instance, the response of alate colonists to visually contrasting vegetation may change temporally across an entire growing season (Costello 1995), highlighting the need for further experiments exploring how the deployment of weedy margins affects aphid populations over longer periods of time. In addition, although the reemay cages were designed to exclude predators and parasitoids such as *C. septempunctata* and *D. rapae,* they were probably less effective at excluding edaphic predators (e.g., carabid beetles), which can be influential in controlling aphid populations (Ekbom et al. 1992, Landis & van der Werf 1997, Losey & Denno 1997). A more detailed assessment of the effects of the margin treatments and exclusion cages directly on the entire predator/parasitoid community is necessary to attain a better understanding of the mechanisms underlying the differences in aphid densities in weedy and bare ground margin plots.

Although the importance of insect dispersal in response to vegetational diversity has been well-documented (Kareiva 1982, Lawrence & Bach 1989, Letourneau 1990), recent explorations have demonstrated that the scale of landscape manipulations may affect dispersal abilities and hence influence insect distributions/densities (Marino & Landis 1996, Roland & Taylor 1997, Banks 1998, 1999). There are thus some difficulties in extrapolating the results from this experiment to larger scale farms, as herbivores and natural enemies alike may respond differently to larger distances between plots and even among plants. Furthermore, it's not clear how to prescribe the optimal size/area of weedy margins in larger plots based on this experiment. An overall increase in plot size would decrease the perimeter-to-area ratio, generating a weedy margin that comprises a smaller percentage of the total plot size. In an earlier experiment, I demonstrated that aphids in particular were sensitive to the percent cover of weeds relative to crop plants in plots in a weed-broccoli agroecosystem (Banks 1998); in light of this and other evidence of scale-dependent processes at work (e.g., microclimate) we should expect difficulties in predicting how "scaling-up" from experimental plots to full-sized farms would affect both herbivores and natural enemies.

Finally, vegetation characteristics such as plant quality and physiology can play an important role in determining how landscape manipulations affect phytophagous insects (Hacker & Bertness 1996). While the current experiment represents a first step towards elucidating the mechanistic underpinning responsible for the herbivore reduction in weedy margin plots, further experiments exploring both biotic (e.g., predator populations, plant physiology) and abiotic (e.g., microclimate, soil conditions) factors and the interaction of the two will enable us to better prescribe the deployment of weedy margins into crop fields as a means of augmenting pest control.

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